SCIENTIFIC RESULTS OF NANSEN'S JOURNEY ACROSS GREENLAND.

DR. FRIDTJOF NANSEN, at a meeting of the Geographical Society of Berlin, Nov. 8, 1890, read a paper on his journey across Greenland, with special reference to the scientific results of the same. By this expedition it is shown ("Proceedings of the Royal Geographical Society," London) that the whole of Greenland south of about 75° north latitude is covered by an immense unbroken coating of inland ice. How far this covering extends over northern Greenland is not yet accurately known. That it must go beyond 75° is evident from the mighty glaciers which project into the sea along the whole of the west coast of Greenland. Of these, the immense glacier at Upernivik shows a movement of as much as 99 feet in 24 hours. Such glaciers must of necessity be fed by an unbroken ice-covering in the interior, because otherwise they would not have sufficient material for their enormous production. Although under 80° north latitude there are large glaciers, like the Humboldt glacier, still the latter appears to have no important motion; and, inasmuch as Grinnell Land also is not completely covered with ice, it is quite possible that the extreme north of Greenland, in consequence of the atmospheric precipitation being too insignificant, is no longer wholly overlaid with this ice-covering.

The highest point reached by the expedition exceeded 8,915 feet, and lies about 112 miles from the east coast and 168 miles from the west coast. But the highest part of the ice does not lie so near to the east coast as might appear from the foregoing: for, in the first place, the route of the expedition was not at right angles to the coast, but inclined to the longitudinal axis of the country, the direction being first north-west and then west-south-west; and, secondly, the land in the interior rises from the south to the north. Consequently the highest point of the ice lies, in fact, nearer the middle of the country than would appear from the route. The periphery of the ice-covering corresponds pretty much to the segment of a circle of about 6,450 miles diameter. The Jensen journey into the interior gives a circular periphery with a radius of 5,560 miles; and Nordenskiöld's journey, one with a radius of 14,530 miles. It follows that the upper side of the inland ice forms a remarkably regular cylindrical surface from one coast to the other, although the radii of this cylinder increase cousiderably from south to north. The underlying land is certainly, as the numerous fiords prove, just as mountainous as Norway. But the fact that the surface of the ice is so regular is due to the pressure of the plastic ice-masses, and the surface of the ice reaches its highest level just where the resistance to this force is greatest. The watershed of the underlying land lies nearer to the east coast than to the west; then the resistance to the pressure of the masses of ice will also be greater on this side than on the west coast, and the high ridges of the ice-covering will also be found to lie between the middle axis of Greenland and the water-divide of the land buried beneath the ice.

The thickness of the Greenland ice, Nansen estimates at from 5,000 to 6,000 feet over the valleys of the underlying land. The pressure of a glacier 6,000 feet high upon its base would amount to at least 160 atmospheres: the ice-masses must therefore exercise a strong moulding influence upon the land. The inland ice at a short distance from the coast is composed of fine dry snow, on the top of which the sun in summer only is powerful enough to form a thin melting crust. The ice-poles six feet long could be driven into these masses without striking firm ice.

The daily variation in the temperature amounted, in the month of September, to from 36° to 45° F. The annual variation must be enormous. The moisture of the air is very great: with few exceptions, it amounted to between 90 and 100 per cent. The number of days of atmospheric precipitation is also large. Of the forty days occupied by the expedition in crossing the ice, four were rainy, snow fell on eleven, and hail on one. Inasmuch as there is now no melting of the ice in the interior of Greenland, and evaporation also is almost *nil*, the chief factor in preventing the further increase of the ice-masses, apart from the great part which is played by the movement of the ice-masses in the direction of the coast, is apparently to be found in the "terrestrial heat." Given the mean annual temperature on the surface of the inland ice at −22 F., and the geo-thermic scale of depth of the ice at about 55½ feet per 1° F., the temperature of the ice would, even at 3,000 feet, stand at melting-point. In any case, an active melting process goes on at the bottom of the ice, and rivers pour forth into the sea from under the ice in winter as well as in summer. Nansen himself had the opportunity of observing this during the most rigorous winter. These streams, which must flow under the enormous pressure of the ice-masses, are powerful eroding agents. The formation of the "asar" in Sweden, and of the "kames" in Scotland, England, and Ireland, are apparently to be accounted for in this way.

LETTERS TO THE EDITOR.

*** Correspondents are requested to be as brief as possible. The writer's name is in all cases required as proof of good faith.*

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What caused the Obliquity of the Ecliptic.

IT is difficult to bring the mind to believe that there ever was a time when there were no seasons, — spring, summer, autumn, and winter, — as now. In attempting to account for natural phenomena, we have nearly always assumed that the axis of the earth was orignally inclined to the plane of the ecliptic at an angle of 23½°, as we now find it, and of course we in consequence have formed in our minds the idea of the annual recurrence of the seasons through all geological time; but the elimination of the seasons from the early history of the earth has been forced upon us by the accumulation of facts from the geological record. There is abundant evidence to prove the existence of tropical or sub-tropical animals and plants in Arctic latitudes as late as the tertiary. In Professor Dana's "Manual of Geology" (third edition, p. 352) that author says, "If we draw any conclusion from the facts, it must be that the temperature of the Arctic zone differed little from that of Europe and America. Through the whole hemisphere, and we may say world, there was a genial atmosphere for one uniform type of vegetables, and there were genial waters for corals and brachiopods." Scarcely any one now, who is conversant with the facts, will deny that the early history of the earth was marked with a uniform, or nearly uniform, temperature, in all latitudes, prior to and including most of the tertiary. The main difference of opinion existing now among scientific men is how to account for such uniform, world climate.

So of the glacial period. Every one admits that the great array of facts justifies the conclusion that the poles of the earth were, since the tertiary, covered with great ice caps or sheets several thousand feet thick, and reaching down to the 40th parallel of latitude, constituting the great glacial epoch. There is a wide divergence of opinion, however, as to the origin or cause of this glacial cold. Mr. Croll, in his "Climate and Time," has formulated a theory, derived from the secular changes in the eccentricity of the earth's orbit, through which he finds a place for the glacial period; but this theory, if true, must provide for alternation of warm and cold periods at the poles throughout all geological time. Professor James Geikie of Scotland, in his "Great Ice Age," indorses this theory, and attempts to find evidences of former glacial action, not only in the tertiary, but also in mesozoic and paleozoic times. But the weight of the evidence seems to be against this theory, and Mr. Geikie himself admits that much of his "evidence" is "not very convincing."

The best and most satisfactory explanation of the warm and cold periods at the poles has been made by Professor C. B. Warring, in a paper read by him before the New York Academy of Science, and published in the *Popular Science Monthly* for July, 1886. This paper merits a much more extended notice than it has apparently received, for its author has very strongly fortified his several propositions. Briefly, his argument is this: The existence of tropical vegetables in Arctic latitudes cannot be supported upon the theory of a warm temperature only. Light was as necessary as heat; and this light must also have been uniform

and unbroken by long periods of darkness, for, if there had been a long night of four months in every year, as now, it would have been fatal to all plants, and even many or most of the animals. Therefore, down to nearly the close of the tertiary, the axis of the earth was perpendicular to the ecliptic, and the days and nights were everywhere and always equal. The temperature was kept up by means of the carbonic acid and aqueous vapor in the atmosphere, which formed a sort of "double blanket," and served to retain the heat radiated from the sun. After a long period the carbonic acid was most of it taken up from the atmosphere to form our coal-beds, peat, petroleum, graphite, etc. This process was followed by a thinning of the retaining cover. The heat from the sun was not all retained, but was lost again by escaping into stellar space. "Holes in the blanket" appeared at the poles, ice and snow began to accumulate there, and eventually the glacial epoch was inaugurated. Furthermore, he shows, that, accaccording to the nebular hypothesis, the axes of the earth and moon ought to have been, in their normal condition, parallel with each other, and both perpendicular to the plane of the ecliptic; but instead, the earth's axis is inclined $23\frac{1}{2}°$, while the moon's axis is practically perpendicular, it being inclined only 1° 30′. The change, therefore, was with that of the earth, and was effected since the moon's separation from the earth. "In view of all these facts," he says, "it seems most probable that in that blank interval the glacial epoch, or more largely between the end of the miocene and the beginning of the Champlain, that movement occurred which gave the earth seasons, unequal days and nights, and greatly enlarged its limits of inhabitability. . . . When the axis became oblique, more solar heat fell within the polar circle, those regions became warmer, and the glacial epoch departed. If these conditions — a perpendicular axis and high uplifts — could be to-day restored, the atmosphere remaining as it is, the glacial epoch would return."

It is the purpose of the present article to emphasize the reasons for believing the direction of the earth's axis was changed about the time stated above, and also to suggest the probable cause of the change. In order to do this more intelligently, we must take a more comprehensive view of the glacial epoch and all its attendant phenomena than is usually found in any one or many of the text-books, or papers, reports, and lectures, upon the subject. Of all the geological changes and revolutions in the earth, out of which has been evolved the present world of animal and plant life, the glacial epoch is certainly the most unique, and full of interest to the scientific observer. What caused the glacial cold has been the constant inquiry, but never answered, ever since it was first proposed some forty or fifty years ago. Why should corals live in security in Spitzbergen, and the red-woods of California and the cypress-trees of the southern United States flourish in the north of Greenland as late as tertiary times, where now are the almost constant rigors of an Arctic winter? What caused the recession of the glaciers, and why may we not have a recurrence of them? What influence, if any, did the polar ice-caps exert upon tho ocean-level and ocean-currents? Were the ice-caps equal in magnitude; and, if not, what effects, if any, followed such inequality, from the attraction of the sun and moon upon the mass of the earth, thus abnormally distributed? These questions and kindred ones must be considered before we are prepared to comprehend the full significance and consequences of the glacial epoch.

It seems incredible that a great ice-cap, several thousand feet thick, should accumulate, and remain throughout the summer, in the temperate zones, if the ecliptic were as oblique in those times as now. The sun on the 21st of June would be nearly perpendicular to the southern limit of the glacier, and would certainly exert a powerful influence in preventing its formation or accumulation south of the northern limits of Minnesota. On the other hand, however, if we place the sun continuously perpendicular at the equator, the temperate zone would be characterized by continual spring weather similar to that occurring in April at the present time. In such case we may readily conclude that the precipitations of snow might be greater than that melted by the slanting rays of the vernal sun, and hence might continue to increase, and form a glacier of ice.

It appears that the polar ice caps in glacial times extended as far as the 40th parallel of latitude from either pole; in some places the north glacier in the United States extended as far south as the 39th, and even to the 38th parallel; and in South America Professor Agassiz found evidences of glacial action as far north as the 37th parallel. Mr. D. Forbes informed Mr. Darwin that he had seen ice-worn rocks and scratched stones at about 12,000 feet height, between 13° and 30° south latitude. There seems also some evidence of glacial action in the south-east corner of Australia. In northern Asia, owing to the great extent of land surface, it may be reasonably inferred that the southern limit of the glacier was much beyond that in the United States. The mountain-ranges in both hemispheres doubtless were covered with a much greater accumulation of snow and ice than they are at present, extending at that time to within the tropics, and perhaps to the equator. But from the whole record, we may safely assume 40° as the average limit of each, the southern being the more widely extended of the two. There are many evidences that these ice-sheets were not confined to the land, but that they crossed gulfs, seas, and even oceans. Professor H. Carvill Lewis, in a lecture published in the *Journal of the Franklin Institute* for April, 1883, says, "It probably also filled the bed of the Atlantic with ice far south of Greenland, the edge of the glacier reaching from New Foundland to southern Ireland in a concave line;" and Professor Geikie says the German Ocean was entirely filled with ice. Similar evidence has been found as to the antarctic glacier. We have therefore two magnificent circular polar ice-caps, each of them nearly 7,000 miles in diameter, and the two covering about 61,000,000 square miles of the earth's surface, leaving a zone of non-glaciated surface at the equator of about 139,000,000 square miles; so that, at the culmination of the glacial epoch, nearly one-third of the earth's surface was covered with ice.

If, now, we could ascertain the thickness of these great glaciers, we could easily estimate the amount of the earth's mass taken up in the form of aqueous vapor, transferred to the polar areas, and there deposited in the form of snow and ice. While admitting the incompleteness of the record, the weight of the evidence at present is to the effect that the antarctic glacier was much larger than the arctic. Upon general reasoning, this ought to have been true; for three-fourths of the land surface of the earth are in the northern hemisphere, and the amount of water surface in the southern and northern hemispheres respectively is in the ratio of 85 to 60 In the southern hemisphere, therefore, there ought to have been a greater amount of evaporation; and, in the absence of any known air-currents to carry this evaporation to the north of the equator, there would necessarily be a greater amount of precipitation in the southern hemisphere, and consequently a greater accumulation of ice. That such was the fact in glacial times, seems to be indicated by what is conceded to be an imperfect record. Professor Dana, in his "Manual of Geology," estimates the thickness of the northern glacier in America to have been 11,500 feet on the watershed of Canada. Professor Le Conte, in his "Elements of Geology," says, "The archæan region of Canada seems to have been . . . covered with a general ice mantle 3,000 to 6,000 feet thick;" and Professor James Geikie says the Scandinavian ice-sheet "could hardly have been less than 6,000 or 7,000 feet thick." As Norway extends nearly to the 72d parallel of north latitude, it is not probable that the northern glacier exceeded two miles in thickness at its greatest height. Professor Le Conte says, "Greenland is apparently entirely covered with an immense sheet of ice, several thousand feet thick, which moves slowly seaward, and enters the ocean through immense fiords. Judging from the immense barrier of icebergs found by Capt. Wilkes on its coast, the antarctic continent is probably even more thickly covered with ice than Greenland." Sir James Clark Ross reports having sailed for several hundred miles along a perpendicular wall of ice 180 to 200 feet high in the antarctic continent, and found only one place where the top of the ice could be seen from the mast-head of his ship; and Capts. Cook and Wilkes both confirm the report of a large ice-sheet in that part of the world. Professor Croll, in "Climate and Time," estimates, from all the data at hand, that the thickness of the southern ice-cap at its greatest height is not

less than twelve miles. It is not probable that the antarctic glacier was much, if any, higher than this in glacial times; for it will be readily understood, that, after the glaciation had proceeded so far as to place the south pole in the midst of a vast ice plain, the incoming clouds from the surrounding oceans would deposit most of their moisture before reaching the centre, and the glacier would be built up at or near its circumference. Hence we should expect to find the glacier, instead of thinning gradually from twelve miles at the centre to nothing at its outward edges, would present more the appearance of a great section of a hollow sphere of nearly uniform thickness, laid over the earth at the pole.

Further confirmation of this view is found in the fact that the southern hemisphere has a cooler mean annual temperature than the northern. Mr. Croll says this is due to the constant transferrence of heat to the north by means of ocean-currents, nearly all the great currents originating south of the equator; while Sir Charles Lyell thinks the true cause lies in the fact of the smaller extent of land surface in the south. It is also true that from March 20 to Sept. 22 — the duration of the sun's northern declination — there are 186 days, while from the autumnal to the vernal equinox there are only 179 days: the northern summer is therefore seven days longer than the southern summer, and the southern winter is that much longer than the northern. If this inequality in the length of the summer and winter in the two hemispheres had its origin during the glacial epoch, it would at least have the effect of melting the ice in the north more rapidly than in the southern hemisphere; and, if it existed before glacial times, the effect would have been to accelerate the growth of the southern ice-cap more rapidly than that of the northern.

At the culmination of the glacial epoch, therefore, we may assume that the northern glacier was of an average thickness of 1 mile, and in extent about 25,000,000 square miles, making 25,000,000 cubic miles of ice; that the area covered by the southern glacier was about 30,000,000 square miles, and 5 miles of average thickness, making 150,000,000 cubic miles of ice; and the two extending over more than one-fourth of the earth's surface, and aggregating 175,000,000 cubic miles of ice. These two gigantic "fossils" would be equal in size to about one-thirtieth part of the bulk of the moon, and would represent an amount of evaporation from the water surface of the earth sufficient to lower the sea-level more than 5,000 feet, or about one mile.

Now, I submit that the attraction of the sun and moon upon this mass of ice would, if continued for a long time, be sufficient to effect some change in the direction of the earth's axis. Just how much that change would be, I have not determined; but that there would be some change seems to be evident from the bare statement of the proposition. When we consider that this matter has been removed to the poles from the equatorial regions, the inequality of distribution of the earth's mass would be greatly augmented. The action and re-action of the sun and moon and the planets on the protuberant mass of matter about the equator produce what is called "nutation," and the procession of the equinoxes. Now, this mass being equally distributed around the earth like a ring at the equator, only the nutation, or nodding, of the axis is produced. But in the case of the antarctic ice-caps the result of the attraction would be somewhat different; for, this being largely at one side or at the pole, and the mean attraction of the moon being in the plane of the ecliptic, its tendency would be to draw the mass towards the ecliptic — so far, at least, until an equilibrium should be found.

That the relative magnitudes of the two polar ice-sheets should always remain the same, would hardly be presumed. The sinking of the ice to the bottom of the Northern Atlantic would necessarily cut off the Gulf Stream, and prevent its further progress northward, if it existed in preglacial times. Even if the ice extended only a few hundred feet below the surface, it would materially interfere with that current, since it is a broad shallow stream, flowing upon the top of the ocean. Similar conditions in the southern ocean might have aided the causes already named in effecting a change or changes in the relative sizes of the two great glaciers. During such changes, therefore, if any existed, oscillations of the earth's axis may have occurred before it became fixed as at present. We should therefore expect to find pauses in the recession, and perhaps a re-advance, of the northern glacier; and such we do actually find from an examination of the great Kettle Moraine in the northern United States, and of the reindeer epoch in Europe.

As already stated, the ocean-level would be very materially lowered. Thus we can account, in part at least, for the land elevations in high latitudes, to which all geologists resort for a partial explanation of glacial phenomena. True, this lowering of the level would be co-extensive with the entire ocean surface; and the old shore-lines would be found, if discovered at all, below the present water-level. But, as Professor Dana says, "elevations of land do not leave accessible records like subsidences." One of the strongest evidences of land elevation is the existence of numerous extensive fiords, which Professor Dana says are "valleys of erosion," and which Professor Le Conte calls "half-submerged glacial valleys." But, as the ice did not exist at sea-level in low latitudes, these fiords are not found there as fossil remains to mark the degree of elevation. But we know that England was united to the continent of Europe by dry land, that the Mediterranean sea was an interlocked fresh-water lake, that the delta of the Mississippi was at least 400 feet higher than it is at present, and that many of the islands of the Pacific Ocean were at a higher level. Professor Winchell, in his "Pre-Adamites," says that probably the now sunken continent of Lemuria, in the Indian Ocean, was dry land during the glacial period, as were also some of the Malay Islands and others. Professor Le Conte says, "The boldness of the whole Pacific coast, especially in high latitudes, indicates a previous more elevated condition of the land surface [during the quaternary] than now exists;" and Mr. Darwin thinks that "at this period of extreme cold the climate under the equator at the level of the sea was about the same with that now felt there at the height of six or seven thousand feet."

Moreover, if this inequality in the amount of the accumulation at the two poles existed as intimated, it would be sufficient to remove the centre of gravity of the earth a little to the southward of its former position. This would be followed by a greater flow of water from the north polar regions; and here we would have another cause of land elevation in high northern latitudes, since lowering the water-level is equivalent to an elevation of the land. While there may have been local elevations and subsidences of the land surface in high latitudes during the glacial and Champlain periods, there seems to be strong reason for believing that the growth and decay of the two great ice-barriers added materially to such changes of level by alternately lowering and elevating the general ocean surface. This lowering of the sea-level might be taken into account in considering the question of the geographical distribution of plants and animals; but it is not my design to pursue that branch of the subject here.

The suggestion here made, that the large accumulation of the earth's mass at the south pole was one of the contributive causes of the change in the direction of the earth's axis, is but a corollary to Dr. Warring's statement, that "between the end of the miocene and the beginning of the Champlain, that movement occurred which gave the earth seasons, unequal days and nights, and greatly enlarged its limits of inhabitability."

T. A. BEREMAN.

Mount Pleasant, Io., Feb. 5.

BOOK-REVIEWS.

Hegel's Logic: a Critical Exposition. By WILLIAM T. HARRIS. Chicago, S. C. Griggs & Co. 16°. $1.50.

WHAT Hegel calls logic is what other folks call metaphysic; and Mr. Harris has here undertaken to tell us what, as he understands it, Hegel's metaphysic is. We say "as he understands it;" for it is notorious that Hegel's disciples have not been agreed as to what his philosophy really is, some giving it a pantheistic or atheistic interpretation, while others, like Mr. Harris, think it a perfect philosophical basis for Christianity. This disagreement is partly due to the obscurity of Hegel's style, which makes it impossible in some cases to understand him, and his disciples have in this respect followed the bad example of their master. The